H. A. NEWTON as far back as 1894, and CALLANDREAU afterwards elaborated the theory of the capture and disintegration of comets.

Professor BROWN'S recent address to the American Association for the Advancement of Science[1] contained his first announcement that the Trojan group of asteroids "appear to show one, perhaps the main, stage of transition from bodies superior to the orbit of *Jupiter* to those inferior to that planet and possibly to those which have become his satellites. Thei· separate paths of motion are interesting to the mathematician, but even more so to the astronomer, since they appear to indicate a new set of periodic orbits in the problem of three bodies. The remarkable series of families of such orbits obtained by Sir GEORGE DARWIN has shown how far such an investigation may lead. . . . Theories as to the mode of formation of our solar system will, I believe, receive some assistance from these orbits of transition."

U. S. NAVAL OBSERVATORY, MARE ISLAND, CAL.
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PERSONAL EQUATION AND ITS VARIATION—DISCUSSION OF SOME CIRCUMSTANCES CAUSING RECORDED TIME OF A STAR'S TRANSIT TO DIFFER FROM TRUE TIME.[2]

By ELLIOTT SMITH.

The recorded time of transit of a star across a wire in the reticle of a transit instrument is rarely the true time. It may be obtained by applying a correction, commonly called personal equation, to the recorded time of transit.

An observer finds that this correction is not the same for all stars and that it varies with the conditions under which observations are made. It is different for stars of different magnitudes and is affected by the observer's position in making the observations. Variation of illumination of the field also produces a variation in this correction.

[1] *Science* for January 20, 1911, p. 93.

[2] Synopsis of thesis published in partial fulfillment of the requirements for the degree of doctor of philosophy in the University of Cincinnati.

It was my purpose in this work to determine my own personal equation and to investigate its variation under the circumstances of varying magnitude, different illumination of field, and different position of the observer in making the observations.

To determine my personal equation, I employed a method which may properly be called a transit micrometer method. It consists in comparing transits made in the ordinary method by pressing a key held in the hand with those automatically recorded while the star was kept bisected by turning the right ascension micrometer head of the meridian circle. With the micrometer head set at the reading $9^r.72$, transits across the first wires of the reticle were recorded with the key. For the following wires the micrometer head was turned backward successively until each in turn met the star in its transit and then turned forward, the observer keeping the star image bisected. A break-circuit was so arranged that at the reading $9^r.72$ in the forward motion of the micrometer head a record of transit was made on the chronograph. Reducing all the observations made of a star to a mean wire, gave a means of comparing directly the times recorded of its transit by the two methods and of deriving the personal equation correction.

It is assumed that personal equation is wholly eliminated when the transit micrometer is used, and this assumption is borne out by some very thorough investigations.[1]

The corrections for personal equation thus derived were classified as $p_2, p_3, p_4, \ldots p_8$. p_2 is the correction for stars between magnitudes 2.0 and 2.9, p_3 that for stars between magnitudes 3.0 and 3.9, and similarly for $p_4, p_5 \ldots p_8$. On an average the final value of each depends upon a comparison of sixty transits recorded automatically with forty recorded with a key. In Table II I give their values as derived by this method. It is interesting to note that the signs of the corrections are negative, showing that the records with the key were made after a true bisection. My mean personal equation is $-0^s.122$.

If we derive the personal equation correction for stars of different magnitudes and find that they have different values,

[1] See Appendix No. 8, Coast and Geodetic Survey Report for 1904.

it is evident that these deviations from a constant value are due to the difference of brightness in the stars. This gives rise to magnitude equations, which may be defined as the outstanding correction to be applied to the observed time of transit of a star of given magnitude, after the correction for personal equation of a star of different magnitude, taken as a standard of comparison, has been applied to it. Assuming that the magnitude equation of stars between $8^m.0$ and $8^m.9$ is zero, we derive the corrections for magnitude equation from Table II by subtracting p_8 from each of the quantities $p_2, p_3 \ldots p_8$. Designating these corrections $m_2, m_3 \ldots m_8$ respectively, we obtain the values given in the first column of Table IV.

TABLE II.
Personal Equation.

p_2	$-0^s.138$
p_3	-0.109
p_4	-0.116
p_5	-0.118
p_6	-0.112
p_7	-0.123
p_8	-0.140
Mean	$-0^s.122$

TABLE IV.
Magnitude Equation.

	Microm.	Screen.	Mean.	Mag. Eq.
m_2	$+0^s.002$	$+0^s.025$	$+0^s.014$	$-0^s.007$
m_3	$+0.031$	$+0.024$	$+0.027$	$+0.006$
m_4	$+0.024$	$+0.018$	$+0.022$	$+0.001$
m_5	$+0.022$	$+0.022$	$+0.022$	$+0.001$
m_6	$+0.028$	$+0.008$	$+0.018$	-0.003
m_7	$+0.017$	$+0.033$	$+0.025$	$+0.004$
m_8	0.000	0.000	0.000	-0.021
Mean	$+0^s.021$	$+0^s.022$	$+0^s.021$	$0^s.000$

Magnitude equation may also be defined as the correction to be applied to the time observed of the transit of a star of one magnitude to reduce it to the time which would have been recorded if the star had been of another specified magnitude.

Taking the same list of stars as was used for the determination of the corrections for personal equation, I derived independently the corrections for magnitude equation by a method suggested by this definition.

Screens were used to reduce all magnitudes to 8.0 . . . 8.9. Screened stars were observed over some of the wires of the reticle and over the other wires they were observed unscreened. All transit records were made with a key. A correction for magnitude equation was directly obtained by reducing all observations of a star's transit to a mean wire and comparing the time recorded of its transit as a screened star with that of its transit when not screened. The resulting values—m_1, m_2,

m_3, . . . m_8—each depend upon about one hundred recorded transits. Their values are given in the second column of Table IV. In the third column are given the mean values of the corrections as derived by the two independent methods. The footing of each column is the mean of the first six numbers in it. If we assume that stars of magnitude 8 + have a correction for magnitude equation of $-0^s.021$, we derive the values given in the fourth column from those of the third.

The results indicate that the corrections for magnitude equation are small and may be considered zero for all stars brighter than the eighth magnitude. A negative correction for faint stars is in accord with results obtained for other observers. My results will receive further verification before they are accepted as definitive and corrections for magnitude equation adopted for my observations.

If the time recorded of the transit of a star observed facing north is different from what it would have been if observed facing south, we may consistently call this difference position-equation. We may arbitrarily define it as a correction to the recorded time of transit of a star for observer facing north, to reduce it to the time which would have been recorded for observer facing south. This definition gives us a clear statement of the correction we wish to find.

For the first series of determinations zenith stars were chosen. With the telescope set for a star of this list, I observed its transit across the first wires of the reticle facing south, changed my position during observation and recorded the time of its transit across the remaining wires facing north. Reducing the observations to a mean wire gave a means of deriving at once the correction for position equation.

From one hundred and forty-four transits the value $-0^s.066$ was obtained. The correction was also derived from clock corrections obtained by observing standard stars at the zenith. This method gave the value $-0^s.065$.

The two methods were also employed to determine this correction for stars between 70° and 80° of declination and gave the identical values $-0^s.074$. From these results it seems evident that the correction is constant for stars north of the zenith.

There is apparently no variation of personal equation with declination for stars south of the zenith. As an indication of this a synopsis of residuals derived from standard stars observed in regular programs of work is given in Table VIII. Residuals from the mean clock correction are considered to be of the form $\Delta\,\alpha \sec\delta$. These residuals may be ascribed to accidental error.

TABLE VIII.—RESIDUALS FROM CLOCK CORRECTIONS IN OBSERVING PROGRAMS.

	1909	Prog.	No. *s	Seeing.	Mean Decl.	Extreme Declinations.		Mean Res.	Mean $\Delta\alpha$	Maximum $\Delta\alpha$
	Sept. 11	153	8	3+	+26°.9	+ 0°.7	+44°.9	±0s.013	±0s.012	+0s.032
	16	154	6	2+	+28 .7	+19 .2	+40 .0	±0 .027	±0 .023	(—)0 .058
	17	155	10	3+	+ 4 .0	—16. 5	+25 .5	±0 .027	±0 .026	(—)0 .046
	18	156	8	2	+ 3 .7	—11 .0	+23 .1	±0 .023	±0 .022	(+)0 .041
	27	157	8	2+	+34 .0	+15 .6	+40 .8	±0 .044	±0 .034	(+)0 .072
	Oct. 2	158	9	3+	+ 2 .3	—15 .1	+24 .4	±0 .014	±0 .014	(—)0 .037
	7	159	9	3+	— 0 .1	—15 .0	+33 .2	±0 .028	±0 .027	(+)0 .059
	16	160	7	3+	— 2 .4	—22 .8	+25 .5	±0 .029	±0 .028	(—)0 .065
	Nov. 11	161	8	3+	— 0 .9	—21 .4	+19 .4	±0 .020	±0 .020	(+)0 .051
	12	162	7	*	+ 2 .3	—27 .9	+19 .0	±0 .044	±0 .041	(+)0 .079 d
	13	163	8	3	— 2 .8	—16 .4	+18 .6	±0 .030	±0 .029	(—)0 .061
	24	164	9	3+	— 3 .9	—30 .1	+29 .7	±0 .048	±0 .036	(—)0 .089 e
a	26	165	7	3+	+32 .3	+26 .9	+38 .0	±0 .019	±0 .016	(—)0 .031
b		165	8		+45 .9	+41 .8	+50 .6	±0 .025	±0 .017	(+)0 .033
a	Dec. 1	166	5	2	+37 .5	+29 .1	+33 .4	±0 .025	±0 .021	(—)0 .033
b		166	4		+47 .3	+41 .9	+50 .6	±0 .025	±0 .017	(—)0 .023
								±0 .027	±0 .025	0 .050

d Observations stopped because of poor seeing.
e Large change in azimuth constant during observations.
a Residuals from θs.
b Residuals from θn.
Probable error of clock correction from one observation, $\pm$ 0s.020 sec δ.

To investigate the effect of variation of illumination of field a list of equatorial stars was chosen. For each star transits were recorded across some of the wires with the field bright, across the remaining wires with the field faint. It was found that this variation in brightness had an appreciable effect upon the transit times recorded and the investigation indicates that it is important to maintain a constant uniform illumination of field.

In differential determination of position from meridian circle observations the absolute value of the observer's personal equa-

tion is not of importance, but any variation from a constant value in a given series of observations will affect the results. The observer should know the circumstances which cause it to vary, and where these variations have been carefully determined corrections may be applied. When possible it is better to make the conditions of observation such that these variations will be eliminated.

THE DEFINITION OF THE TERM DOUBLE STAR.

By R. G. Aitken,

The limits of distance and magnitude within which a pair of stars must come to be entitled to the classification of *double star* have been left, up to this time, entirely to the discretion of the individual observer. Thus Struve's distance limit is 32″, Espin's 10″, my own 5″. The result is that hardly any two catalogues of double-star discoveries are comparable with each other, and that a complete catalogue, like Burnham's "General Catalogue," contains a most heterogeneous collection of objects. The question arises whether it is not desirable to change this condition so far as future work is concerned.

Any definition of a double star must, in the nature of the case, be more or less arbitrary, for it is obviously impossible to discriminate by any descriptive terms between a pair of stars which constitute a physical system (binary stars) and a pair that is merely associated optically. The choice rests between as many arbitrary definitions as there are observers, and a single working definition adopted by general agreement.

In framing a working definition certain principles must be observed: (1) While it is not essential nor, indeed, possible to set limits of distance and magnitude that will include all possible physical systems, they should be so drawn as to include substantially all pairs likely to prove of interest as binaries, while excluding most of the merely optical pairs; (2) The limits should be simple enough to be easily remembered and applied by the observer at the telescope; (3) Provision should be made for exceptional pairs of stars beyond the adopted limits.